

THE EFFECT OF HYPOPHYSECTOMY IN THE EARLY EMBRYO UPON THE GROWTH AND DEVELOPMENT OF THE FROG

A PRELIMINARY REPORT

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TEN FIGURES

The extirpation of the hypophysis in the adult frog has not given uniform results. Caselli ('00) and Gaglio ('02) who reported no changes following hypophysectomies were followed by Boteano ('06) who reported a neuromuscular asthenia in the operated animals. Houssay ('10) came to the conclusion that the removal of the gland was followed by death. Adler ('14) burned out the hypophysis of a 20 mm. *Rana temporaria* larvae with the electric cautery. Out of the 1200 operated animals three were found to have been hypophysectomized, not, however, without great injury to the surrounding soft parts, particularly the brain. In not one of those three animals did hind legs develop beyond a small bud, and transformation did not take place, the specimens remaining as neotonic tadpoles.

This work was commenced in the Spring of 1914, repeated in 1915, and again in 1916, *Diemyctylus torosus*, *Rana pipiens*, and *Rana boylei* being successively used. In this paper the results obtained with the California yellow-legged frog, *R. boylei* are reported. Shortly after the closure of the medullary plate, Kopsch's stages d-e, was found to be the size in which the hypophysial invagination could be most successfully removed. About 200 larvae of this stage were operated upon. In specimens of this size the hypophysis was successfully removed in over 60 per cent of the operated animals. Approximately 30 per cent of those animals in which the gland was extirpated did

not give reliable results in the rate of growth as the mouth was wholly or partially removed thus interfering with feeding. Unoperated animals and those in which the ablation of the gland was unsuccessfully attempted were available for checks.

The operation is a simple procedure. The hypophysial invagination can be accurately determined from the pit that it early forms or from its location between the protuberance of the forebrain and the stomadeum, which is just forming. This epithelial ingrowth was removed with some neighboring epithelium. The wound healed within three hours in most cases, less than 1 per cent of the larvae disintegrating after the operation. The operated animals and checks were kept in boiled water for five days and then transferred to a frog tank where they were in an essentially normal environment.

The rate of growth in the hypophysis-free animals has been slower than in the checks. The larger hypophysectomized animals averaged smaller in size than the larger checks, the averages of the two showing a noticeable difference. On June 6 the operated but not hypophysectomized animals had an average length of 40 to 43 mm., the hypophysis-free animals averaging 33 to 35 mm., a ratio constant throughout their growth. The ratio of body to tail length is the same in the two classes, the difference in size being uniform for all parts of the animal. The tail fin did not show an increased width or pleating in the hypophysectomized animals as reported by Adler ('14).

In activity the two classes of animals showed no marked differences. The hypophysectomized specimens were perhaps slightly more alert, darted more quickly, and consequently were more difficult to capture with the pipette than were the checks.

The resistance of the hypophysectomized animals was greater than that of the checks. Towards the close of the experiment the animals were attacked by disease, none reaching the adult stage. The normal specimens succumbed more rapidly to this infection than did the hypophysectomized ones. Some of the intrinsic factors which induce growth of legs and transformation were lacking in the abnormal specimens as will be shown later. The absence of these factors may well be conducive to a greater

hardiness in an animal when compared to the normal tadpole in which the usual rapid changes are taking place.

Differences in color began to be noticeable before a length of 15 mm. was reached, and from then on the contrast in pigmentation between the hypophysectomized animals and the checks was striking. Those animals without hypophyses were characterized by a light grayish appearance; however, the dorsal side was more pigmented than the ventral (figs. 7, 10). These are referred to as albinos. The checks were a brown-black color often showing a mottling (figs. 8, 9). This color difference was more noticeable over the body than on the tail, but was evident in both regions and was the most striking feature up to the time of the appearance of the hind legs in the checks. Sections show that these pigment differences are referable chiefly, if not solely, to the condition of the epidermis. Counts of the melanophores of corresponding areas in the albinos and in the checks show that the number of these cells, in the epidermis, are reduced in the former. Further the melanophores of the albino specimens contain fewer pigment granules than do those of the checks and thus have a distinctly lighter appearance. The melanophores are equally expanded in the two types, consequently, the lighter color of the albinos cannot be due to the contracted condition of the chromatophores but must be referred, in part, to the reduced number of melanin granules in the pigment cells of the epidermis. In addition to this the free pigment granules which form a distinct zone in the superficial layer of the epidermis in the normal checks are much reduced in number in the albino specimens (figs. 5, 6). It is surprising that in the albinos the deeper or subcutaneous pigment is present in as great a quantity as in the normal animals, if not greater. The amount and distribution of the retinal pigment seem to be identical in the two.

Another important feature was the inhibition in growth of the hind legs of the operated animals. There was only a slight retardation in the time of appearance of the hind leg buds, normally, appearing when the tadpole has reached a length of 25 to 27 mm. In the albino, averages show that the hind limb buds appear when the larvae are from 26 to 28 mm. in length.

From this state on, however, the hind limbs in an hypophysectomized animal grew but little if at all, although the animal's length increased at a rate but slightly under the normal. The accompanying table shows the increase in length of the hind legs in relation to total length for the albinos and for the checks. (See also figs. 7, 8).

Average rate of growth in millimeters in terms of total length, of the hind legs of the checks and the albinos

HYPOPHYSECTOMIZED ANIMALS		CHECKS	
Total length	Hind leg length	Total length	Hind leg length
26	barely visible	25	barely visible
28	0.1	28	1.0
30	0.1	30	2.0
35	0.1	35	3.0
37	0.12	38	4.0
		40	5.0
		45	9.0

Only one exception to the rule that no hind legs grew on albinos was found. A 36 mm. albino had hind legs 4.2 mm. long when killed. The above is in accord with Adler ('14) who found that removal of the hypophysis in a 20 mm. stage inhibited the growth of the hind legs.

Examination of sections of albino and normal animals shows striking differences in the endocrine glands. The sectioned hypophysectomized animals show no trace of the anterior lobe of the hypophysis. That part of the floor of the diencephalon which normally abuts against the hypophysis, rests upon the floor of the cranium (fig. 2). This apparently demonstrates conclusively that the entoderm has not the intrinsic power to form a hypophysis. If it enters into the formation of the gland at all it must be considered as a tissue inclusion which became changed through its adaptability into glandular parenchyma, a conclusion previously drawn by the writer, Smith ('14). The infundibulum shows some structural modifications when compared to the checks, although the saccus vasculosus, as far as determined, appears to be normal. In the checks that region of the diencephalon which rests against the pars glandularis is



Fig. 1 A section through the hypophysial region of a 38 mm. normal tadpole. $\times 100$.

Fig. 2 A section through the hypophysial region of a 37 mm. albino. Note the much reduced pars nervosa. $\times 100$.

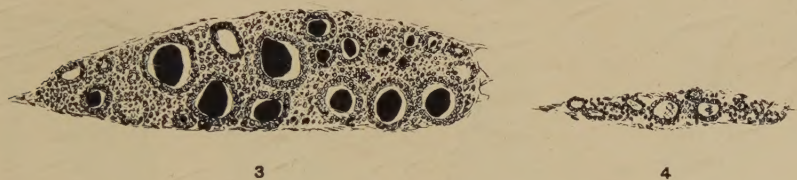


Fig. 3 A sagittal section through a lobe of the thyroid of a 38 mm. check. $\times 100$.

Fig. 4 A sagittal section through a lobe of the thyroid of a 37 mm. albino. $\times 100$.

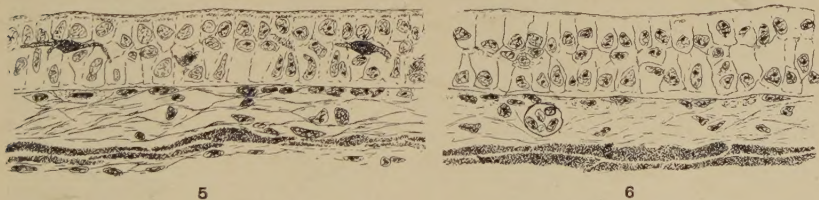


Fig. 5 A section through the epidermis, in the mid-brain region, of a normal 39 mm. check. The pigment granules are indicated by dots. $\times 200$.

Fig. 6 A section through the epidermis, in the mid-brain region, of a 38 mm. albino. A faint melanophore in the left part of the figure. $\times 200$.

of considerable thickness, that is, in addition to the ependyma there is a rudimentary pars nervosa. Caudad to this the wall is formed almost entirely of ependyma. The pars nervosa is reduced throughout most of its extent to an ependymal layer in the hypophysectomized animals. There may be a small localized thickening but nothing to correspond to the normal animal (figs. 1, 2).

The thyroid shows marked modifications in the albinos. In the accompanying table the size of one lobe of the thyroid of a normal 38 mm. tadpole with 4.0 hind legs and of a 37.0 mm. albino with 0.1 mm. hind legs is given.

<i>Size in millimeters of one lobe of the thyroid</i>			
<i>38 mm. check</i>		<i>37 mm. albino</i>	
Length.....	0.6	Length.....	0.21
Width.....	0.3	Width.....	0.15
Thickness.....	0.16	Thickness..	0.04

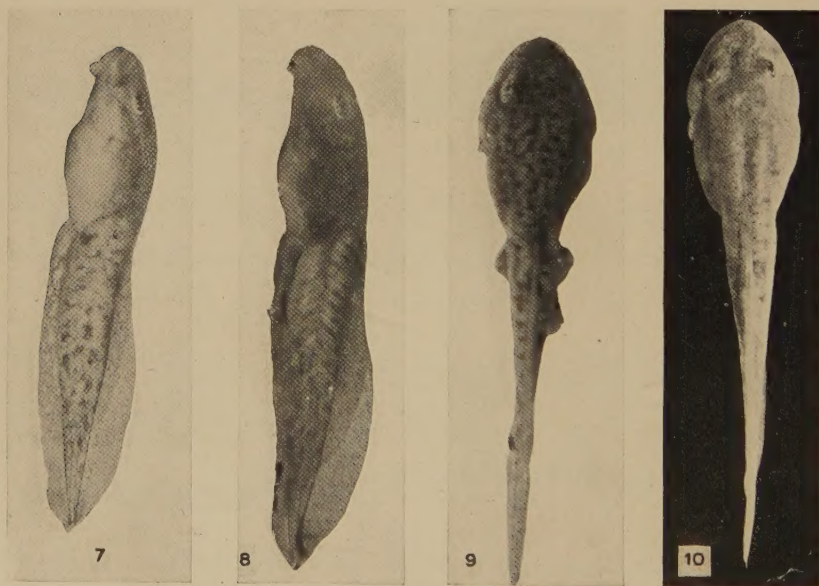


Fig. 7 Photograph of an albino. $\times 2$. Note the very small hind limb bud.

Fig. 8 Photograph of a normal tadpole. Figures 7 and 8 were photographed on the same plate $\times 2$.

Fig. 9 Photograph of a normal tadpole. $\times 2$.

Fig. 10 Photograph of an albino. $\times 2$.

The above table shows that the thyroid of the albino is approximately one-third normal size. The contrast is even more striking when the compactness and character of the parenchyma is noted. A sagittal section through the thyroid of a 38 mm. check shows on an average 12 to 15 vesicles, many of which are largely distended with colloid, the parenchyma of the whole gland being compacted together. A sagittal section through the thyroid of a hypophysectomized 37 mm. specimen shows 6 to 8 atrophied vesicles containing but a slight amount, or no colloid, and with large spaces between the vesicles. The cells making up the vesicles of the former are cuboidal and protoplasmic-rich, in the latter little but the nuclei remain (figs. 3, 4). The results from experimental feeding of thyroid by Gudernatsch and other workers suggests that the non-development of the hind legs in the albinos is due not to the hypophysis but rather to the failure of the thyroid. In this connection the 36 mm. albino with 4.2 mm. hind legs, mentioned above, is of interest. Sections of this specimen show that the hypophysis was completely ablated but that the thyroid is normal. This specimen thus gives additional evidence that the retarded development of the hind legs must be referred to the thyroid and not to the hypophysis. Also the reduction in pigment is not due to the atrophy of the thyroids. The modifications of the thyroid obtained by Adler ('14) were similar but less striking.

An examination of a large number of male and female albinos and checks has, as yet, failed to show any constant variation from the normal in the sex glands of the hypophysectomized animals. The sex glands of the albinos although varying considerably apparently do not exceed the limit of variation met with constantly in the normal animals. This conclusion stands in contradiction to the results previously adduced by the author and to the results of Adler ('14) in the hypophysectomized tadpole and to the conclusions of Hahn ('12) in the tadpole with hypertrophied hypophysis as well to the results obtained in mammals by pituitary feeding, notably that of Goetsch ('16).

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ANOMALIES IN LOBATION OF LUNGS WITH REVIEW OF LITERATURE

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FIVE FIGURES

Judging from the literature, abnormal lobation of the lungs is relatively rare.

Lindsay ('10) divided the abnormalities in the lobation of the lungs into two classes: those in which the normal number is decreased and those in which the number of lobes is increased. The former is due either to a deficiency of the lobes themselves, or to a deficiency of the fissures, which normally separate the lobes. The latter is due to an increase of lobes, or to an increase in fissures. Complete absence of lobation in definitely formed lungs is rarely if ever found, though its homologue is to be found in the Orang, with two lungs each existing as single lobes.

Rokitansky ('61) showed that arrests of development may occur and that this may lead to complete absence or great deficiency of one or both lobes. This arrest may be so early that the lungs can scarcely be observed as small round bodies situated at the ends of the bronchi. This condition is generally due to contraction of the volume of the thorax.

Pontif ('60) in 'Virchows Archives' recorded a case in which the right bronchus was connected with an ovoid body, which was imbedded in gelatinous tissue and filled the right half of the thorax.

According to Lindsay, cases of class two, that is those which have an excessive number of fissures, are occasionally encountered, and are probably the most common form of abnormality. They do not appear to present any regularity, and lack the interest which is attached to accessory lobes. There are two

groups of accessory lobes. One which is of considerable developmental interest, is composed of completely isolated masses of pulmonary tissue formed between the diaphragm and the base of the left lung; occasionally on the right side such masses are found even in the abdominal cavity. Other masses containing arteries, veins, nerves, and bronchial tissue, but devoid of bronchi, are attached to the oesophagus, aorta or other mediastinal structures by a pedicle. These masses are apparently quite functionless. Two such cases are recorded by Vogel ('99), in each of which he found a deficiency in the bronchial tree. Simpson ('99) described a case of a deficient bronchial tree found in a foetus.

In the cases with additional fissures there is a normally placed lung presenting an excessive number of lobes. These abnormalities are usually very definite in their position, and occur more commonly on the right side.

Wrisberg ('77), who was the first to notice an accessory lobe in the human lung, recorded a most interesting and unique case of an accessory lobe on the left side produced by the left azygous vein; i.e., the superior intercostal vein which preserved its foetal condition and opened into the left innominate vein.

Chiene ('76), described a pear-shaped supernumerary lobe, lying between the upper lobe of the right lung and the bodies of the dorsal vertebrae, having its origin from the angle formed by the junction of the upper lobe with the root of the lung. The supernumerary lobe was separated from the upper lobe of the lung by a double fold of the pleural membrane, which descended vertically for seven centimeters from the apex of the thoracic cavity where it was continuous with the pleura costalis. It enclosed in its free border the vena azygous, and formed the outer wall of the cul-de-sac, in which the supernumerary lobe was contained. The left side of the chest was normal; both sides were healthy.

E. W. Collins ('88), recorded a case of an accessory lobe immediately above the posterior part of the root in the angle between it and the upper portion of the right lung. This accessory lobe was somewhat pyriform in shape, with a broad pedun-

cular attachment. In all, Collins was able to collect seven cases of accessory lobes in human lungs.

A. E. Maryland ('90) described abnormalities in lobes of three lungs. The first was a right lung with no indications of a middle lobe, but a development of a third, or accessory one, on the inner side of the lung. The second was a left lung with a subdivision of the upper lobe. The third was a right lung with an incomplete separation of a normal middle lobe. Maryland states: "Cases of more than four right lobes and three left lobes are exceedingly rare."

Patterson ('09-'10) described a condition of two additional lobes. One of these was above the root, and separated from the upper lobe by a fissure. This accessory lobe was enclosed within a pleural pouch, which contained the vena azygous. The second additional lobe was below the root, and between the upper and middle lobes.

Case I of the present specimens presents features entirely different from those hitherto described. It was obtained in the dissecting room during the term of 1915-1916 from a male subject, aged sixty-one. The cause of death as given on the death certificate was dementia. No clinical history was obtainable. Besides the anomalous condition of the lungs, there was a persistent thymus, and a number of anomalous arteries. On gross inspection the lungs presented no pathologic lesions.

The left lung apex-base measured 22 cm., dorso-ventrally 20 cm. The normal fissure (*F3*), which separated the superior from the inferior lobe, was in its normal position, starting at the junction of the antero-inferior border 25 cm. from the apex, and running obliquely upward and backward, dividing the superior and inferior portions completely.

The superior portion, however, presented two other fissures, as shown in the diagram, thus dividing this portion into three more or less distinct lobes.

Fissure number one (*F1*) started at the anterior border 7 cm. below the apex, and ran horizontally backward on the antero-lateral surface of the lung for 6 cm. The depth of the fissure was on an average 1.5 cm.

Fissure number two (*F2*) started at the antero-median border 17 cm. below the apex and ran upward and backward for 9 cm. This fissure extended through the lung tissue, completely separating the middle from the inferior division of the superior lobe. Neither of the two mentioned fissures extended as far as the main fissure, which separated the superior from the inferior lobe.

Three distinct divisions of the superior lobe were evident from an antero-lateral view. The upper division (*L1*) was pyramidal in



Fig. 1 Anterior aspect

shape, forming the apex. It measured 8 cm. antero-posteriorly, and 7 cm. from apex to base.

The middle portion (*L2*) was wedge-shaped, wider on the anterior border than on the posterior. It measured 9 cm. on the anterior border between the first and second fissures, and 17 cm. antero-posteriorly.

The lower division (*L3*) is lingual in shape. This division measured 6 cm. on the anterior border, and 21 cm. antero-posteriorly.

The inferior lobe presented two more supernumerary fissures as did the superior lobe.

Fissure number four (*F4*) started 5 cm. antero-inferiorly from the supero-inferior fissure and ran parallel with the above fissure for a distance of 10 cm. This fissure also extended through the lung tissue separating the upper from the postero-inferior divisions.

Fissure number five (*F5*) was on the lateral surface, extending obliquely, superiorly and inferiorly, and incompletely dividing the postero-lateral from the postero-inferior divisions.

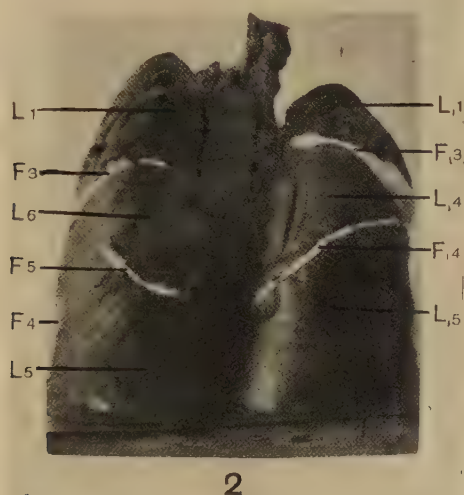


Fig. 2 Posterior aspect

The inferior lobe, which was triangular, also presented three fairly distinct divisions.

The upper division (*L4*), which is oblong in shape, having a small tongue-like projection on the anterior border, ran obliquely upward, and backward, following the direction of the supero-inferior, or great fissure. This division measured 5 cm. antero-inferiorly, and 19 cm. antero-posteriorly.

The postero-inferior division (*L5*) was more or less quadrangular in shape. It measured 8 cm. on the superior border and 12 cm. on the inferior border, i.e., at the base.

The postero-lateral division (*L6*) was irregular in outline. The upper border was made by the supero-inferior fissure, and

the lower by a separate fissure between this division and the postero-inferior division.

The right lung apex-base measured 19 cm., and dorso-ventrally 18 cm. In this lung the fissures were deeper, and went through the lung tissue, completely dividing the lung into distinct divisions. The normal fissure ($F'3$), which divided the apex lobe and middle lobe from the inferior, or base lobe, was a little more irregular than the corresponding fissure on the left lung,



Fig. 3 Right lung: lateral view

and ran obliquely upward and backward, dividing the lung into an upper and lower division.

The upper division presented an irregular outline from a lateral view. There were two large fissures; one which normally divided the apex lobe from the middle lobe, and the other a supernumerary fissure dividing the middle lobe into two. There was also a small fissure in the apex lobe.

Fissure number one ($F'1$), which divided the apex lobe from the middle one, started 10 cm. from the apex laterally, midway between the apex and the base.

Fissure number two ($F'2$), which divided the middle lobe into two divisions, ran vertically for a distance of 8 cm., starting from the base and running toward the apex.

The apex lobe ($L'1$) was quadrilateral in shape, having the upper border narrower than the base and measuring 9 cm. apex-base, and 8 cm. antero-posteriorly.

The inferior division ($L'2$) of the upper lobe was lingual in shape, extending obliquely upward and backward 13 cm. in its long direction, and measuring 4 cm. apex-base.

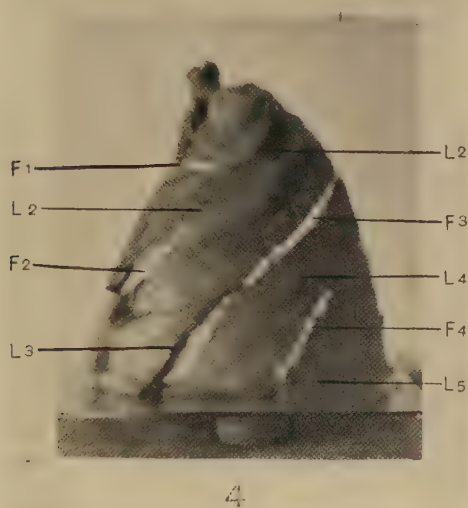


Fig. 4 Left lung: lateral view

The inferior division ($L'3$) of the upper half of the lung was elongated in outline measuring 4 cm. in antero-posterior direction, and 13 cm. apex-base.

The lower half of the right lung was triangular in shape, having two clearly visible fissures which ran through the lung tissue and divided this portion of the lung into three distinct lobes. There are also two smaller fissures in the inferior border of the lung, merely forming small tongue-like lobules.

The fourth fissure ($F'4$) started 10 cm. from the apex midway between apex-base, running downward and backward for a dis-

tance of 14 cm., and completely separating the upper from the lower division of this half of the right lung.

The fifth fissure ($F'5$) started from the base, or inferior border, and ran vertically upward for a distance of 10 cm. It extended through the lung tissue, dividing this inferior half into two divisions, a posterior and an antero-median.

The superior division ($L'4$) of this inferior half of the right lung was triangular in shape, measuring 13 cm. on its inferior

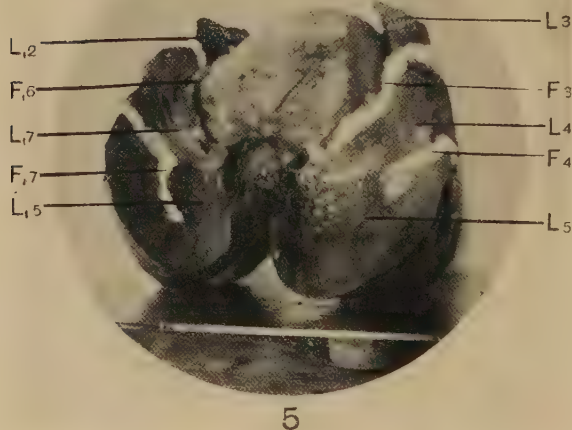


Fig. 5 Base

border, 8 cm. on its superior border, and 11 cm. on its posterior border.

The postero-inferior division ($L'5$) was quadrilateral in outline, measuring 8 cm. on its shortest border and 14 cm. on its longest, or posterior border.

The antero-median division ($L'6$) had the form of an elongated triangle, measuring 11 cm. on the anterior border, 6 cm. on the median posterior border.

At the base of the right lung was a very irregularly shaped division distinctly separate from the rest of the lung as shown

in the diagram. This basal division (*L* 7) measured 10 cm. in the long direction and 6 cm. in the short direction. This division was separated from the rest of the lung by two distinct fissures (*F*'6-7) which started at the postero-inferior border, and ran for 9 cm. anteriorly and backwards.

Case II was obtained in the dissecting room during the term 1915-1916, from a female subject, aged thirty-eight.

The cause of death as given on the death certificate was 'septic meningitis.' No clinical history was obtainable.

The left lung apex-base measured 20 cm., dorso-ventrally 18 cm. The right lung apex-base measured 18 cm., dorso-ventrally 17 cm.

The left lung presented upon examination one accessory lobe, one accessory lobule, and three accessory fissures in the inferior portion of the left lung.

The right lung presented upon examination two accessory lobes and two accessory fissures. The first accessory lobe was in the upper portion of the inferior division of the right lung. The other accessory lobe was a basal lobe and was identical with the basal lobe seen in the right lung in Case I.

X-Ray¹ pictures of Case II show separate bronchi going to each of the main lobes including the accessory lobes, as may be seen by referring to the plates.

X-Ray views of Case I were unsuccessful on account of a poor bismuth injection.

From the foregoing description it is evident that these specimens show no distinct azygous lobe, which is the common accessory lobe described. These lungs retain their normal shape; but they present, besides the normal fissures, a number of accessory fissures which divide the lungs into distinct accessory lobes.

Complete absence or deficiency of one or both lobes may be due as Rokitsansky points out to arrests of development as contraction of the volume of the thorax. Supernumerary lobes have been variously explained. Lindsay ascribes a slight adhesion of the lungs to the thoracic wall as the cause of the super-

¹ Stereoscopic X-ray plates show the separate bronchi as described. Reduced prints fail to show the necessary details and, therefore, are not reproduced here.

numerary lobe, or possibly an undue curvature of the embryo, so that the Venae Cavae, as it bent down to a position at right angles to its original position, instead of slipping behind the pleura and lung, dragged down a fold of the former and deeply notched the latter.

Fischer remarks that it is difficult to conceive of the azygous lobe without an already preëxisting anomalous course of the azygous, and makes no attempt to explain the phenomenon.

Collins explains the azygous lobe as a persistent foetal condition of the left azygous vein.

All previous attempts to explain the origin of the supernumerary lobes apply only to cases in which there is a definite azygous lobe. The anomalous course of the azygous vein has constricted off a portion of the lung tissue, thereby forming a new lobe. This explanation does not apply to cases in which there are no azygous lobes and in which, however, there are other supernumerary lobes, as the azygous lobes are not in reality true lobes. A true lobe as applied to the lung indicates a separate bronchus. Whether the azygous lobe has a separate bronchus, or not, has not been stated in their descriptions.

Considered from the viewpoint of their origin, a constricted portion—such as the azygous lobe—is not a separate entity, but a part of the mother lobe from which it has separated.

The formation of lobes of the lungs has first been studied by Aeby and was worked out by Narath. Aeby defines lung lobe as follows: "A true lobe is never supported by more than a single bronchus and therefore includes no portion of the stem bronchus." Soon after the formation of the first lateral bud in the embryo, each bud becomes marked out upon the surface of the mesodermal anlage of the lung. Before development of lateral bronchi, the surface of this anlage is smooth. Later it becomes almost mulberry-shaped, and secondary elevations are then formed by the budding of the bronchial bud which it contains. The process goes on until the surface becomes covered with fine granules. These disappear with further growth of the lung—only the first formed furrows persisting normally.

Accessory lobes may then be due to a retention of the foetal condition in which not only the primary divisions persist, but on account of the rather slow growth of the bronchi, the secondary conditions persist—that is to say, accessory lobes are not new formations, but represent a stage in the normal development of the lung.

Accessory fissures dividing the lobe into a number of lobules—as exists in the present specimens—may have been due to folds of splanchnopleura which have been carried down and caused the formation of a groove, lined with pleura, or they may have been caused by incomplete obliteration of the secondary divisions, which are produced in the mulberry stage and which normally disappear.

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ANOMALOUS RENAL VESSELS AND THEIR SURGICAL SIGNIFICANCE

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NINE FIGURES

Abnormalities of the renal arteries occur more frequently, perhaps, than anomalies of any of the other larger vessels. In view of the enormous number of investigations of the different structures of the kidneys recorded in the literature on the subject, it seems strange that only scanty information exists concerning the actual course of the larger blood vessels, and their relations to the pelvis of the kidney. The normal, as well as the abnormal, arrangement of the renal vessels at the hilum is known; the microscopic picture of the vessels in the cortex and pyramids are likewise thoroughly familiar to every student; but as to the form of the pelvis, and the actual course and distribution of the larger vessels around its walls, very vague ideas still prevail.

Professor Thane states that irregularities of the renal arteries are met with in about 25 per cent of cases, and that the most common irregularity is the presence of an additional vessel in about 20 per cent.

Young and Thompson report four cases of anomalous renal arteries: the first is that of multiple renal arteries and malposition of the right kidney; the second that of multiple renal arteries, malposition, and malformation of both kidneys; the third that of a horseshoe kidney with multiple renal arteries; the fourth that of multiple renal arteries, two of which were on the left side, two on the right. In the last case there were also multiple spermatic arteries, and two renal veins on the right side, while the left side was normal.

Irregularities in renal vessels have also been mentioned by McAllister ('83) who found anomalous renal arteries in 43 per cent of the cases examined. Levings ('12) reported two cases of anomalous renal vessels going to the lower poles. Harvey ('14) described a case of multiple renal arteries.

The specimens of the present description were obtained in the dissecting room through the help of Dr. E. B. Trovillion, Instructor in Anatomy, University of Colorado; and from autopsies through the courtesy of Dr. R. C. Whitman, Professor of Pathology, University of Colorado. We were able to examine, in all, 33 cases of which 22, or 73 per cent possessed anomalous renal vessels.

Case I. The kidneys were normally placed in the abdominal cavity. Both were somewhat smaller than normal. The right showed two small cysts on its anterior surface. It lacked the normal large renal artery, but possessed instead two renal arteries of equal size, which were almost as large as the normal vessel should have been. The lower artery arose from the ventro-lateral portion of the aorta, 6 cm. above its bifurcation, and passed to the lower pole where it divided into two vessels, 2 cm. before it entered the kidney substance. The second artery arose from the aorta 6 cm. above the lower one, and split into two vessels 2 cm. before it reached the kidney substance. There were also two large renal veins, closely accompanying the arteries; one arising from the upper, the other from the lower pole of the kidney. Both veins emptied into the vena cava.

The left kidney possessed three renal arteries and one renal vein. The lowest renal artery arose from the left ventral portion of the aorta 4 cm. above the bifurcation of the aorta, and supplied the lower pole of the kidney. The second artery arose from the aorta 6 cm. above the first, and supplied the upper pole. The third arose 1 cm. above the second, crossed it and entered the kidney at the hilum. One large renal vein arose from the kidney at the hilum.

Case II. Both kidneys were larger than normal, and in the proper position. The right possessed one renal artery and one renal vein. The left kidney, however, possessed three main renal arteries, and one renal vein. The first renal artery, which seemed to be the normal vessel, arose from the ventro-lateral aspect of the aorta just opposite the origin of the superior mesenteric artery. The second renal artery arose 1 cm. above the first. This was a long slender artery having a tortuous direction, and entered the kidney 4 cm. above the inferior border. The third artery was the smallest, and arose from the aorta just lateral to the second. This artery broke up into three smaller branches, all of which supplied the upper pole of the kidney. The veins were normal.

Case III. This presented two normally placed kidneys, the right being smaller than the left. The right kidney presented upon examination two renal arteries and one renal vein. The lower renal artery arose 2 cm. above the bifurcation of the aorta from its ventral aspect, and entered the kidney at the lower pole 1 cm. above the inferior border. The upper renal artery, which was the normal one, arose from the dorsal aspect of the aorta 11 cm. above the bifurcation of the latter, and, after running a tortuous course, entered the kidney at the hilum. The left kidney was normal. Two spermatic veins emptied into the left renal vein.

Case IV. This presented upon examination two normally placed kidneys. The right possessed two arteries; the normal one arose from the aorta, and entered the kidney at the hilum; the anomalous one arose from the ventro-lateral aspect of the aorta 5 cm. above the normal renal vessel, and entered the upper pole after it had split into two branches.

The left kidney also possessed two arteries; the normal one coming from the ventro-lateral aspect of the aorta just opposite the normal right renal artery, and entering the kidney at the hilum; the accessory renal artery branching from the superior mesenteric, and entering the upper pole of the left kidney 3 cm. below the superior border. The veins in both kidneys were normal.

Case V. This subject presented two normally placed kidneys of normal size. The right kidney contained a small anomalous artery arising from the aorta, and supplying the upper pole. The left kidney was normal, as were also the veins.

Case VI. This presented two normally placed kidneys. The right contained four large renal arteries and two large renal veins. The first renal artery arose from the ventro-lateral aspect of the aorta 3 cm. above the bifurcation, and entered the kidney on the posterior surface of the lower pole 3 cm. above the inferior border. The second and third arteries took origin from the aorta at the ventral surface as a common large branch 1 cm. above the bifurcation but immediately divided into two rather large branches, which entered the kidney at the hilum. The fourth artery was a long slender one coming from the coeliac axis, and entering the kidney at the upper pole 4 cm. below the superior border. There were two renal veins present; a large one entering the vena cava, and another somewhat smaller one also entering the posterior aspect of the vena cava. The left kidney possessed one accessory artery arising directly from the aorta and entering the kidney substance at the lower pole.

Case VII. This was a case of a right kidney with a small accessory artery arising just above the normal renal artery, and entering the kidney at the upper pole 3 cm. below the superior border.

Case VIII. In this case the left kidney was somewhat larger than normal, and contained three large renal arteries, one of which divided into three smaller branches. The first artery arose from the aorta, and entered the kidney at the lower pole, 4 cm. above the inferior

border. The second artery was the largest of the three. It arose from the aorta above the first, and entered the kidney at the hilum. The third artery arose from the aorta above the second, and divided into three smaller branches all of which supplied the upper pole. Two large renal veins were present which arose from the hilum and entered the vena cava.

Case IX. Both kidneys were normal in size and position. On the right side one large arterial trunk sprang from the aorta. This divided into two rather long slender branches after it had continued its course for 2 cm. Each of the two branches further divided into two other branches, thus four arteries entered the kidney: two at the upper pole 3 cm. below the superior border; the other two at the lower pole 4 cm. above the inferior border. Connecting the main renal trunk with the aorta was a plexus of vessels of varying sizes. This plexus, covering the walls of the aorta, appeared to be a persistence of the embryonic periaortic plexus. There was one renal vein which came from the hilum and entered the vena cava.

The left kidney possessed two large and two small arteries. The first, which seemed to be the normal one, arose directly from the aorta and entered the kidney at the hilum. The second artery, which was a long slender vessel, came from the aorta and entered the anterior surface of the kidney 4 cm. below the superior border. On the left side two small arteries came from a plexus which resembled the periaortic plexus. On this side, these small arteries entered the kidney substance, while on the right side the plexus merely connected the large renal vessels with the aorta.

There were also two large renal veins, two smaller veins and a plexus of still smaller veins. This plexus connected the larger veins with the vena cava. The largest vein, which seemed to be the normal one, came from the hilum of the kidney and entered the vena cava. The second large renal vein, which was a long slender one, connected the left spermatic vein with the anterior surface of the kidney. The plexus not only connected the vena cava with the large renal veins, but also formed an anastomosis between this venous plexus and the arterial plexus, so that the venous and arterial blood had a chance to mix.

Cases X, XI, XII, and XIII. These four subjects had kidneys which were similar in most respects. There were two renal arteries arising from the aorta and entering the hila of the right and left kidneys in each case. The veins were normal.

Cases XIV, XV and XVI. These three cases possessed small accessory arteries arising from the aorta and entering the poles of the kidneys. In cases fourteen and fifteen the accessory arteries entered the lower poles, and in case sixteen the small arteries entered the upper pole.

Case XVII. This case possessed four arteries to the right kidney and three to the left, all of which arose directly from the aorta. There were also two renal veins from the left kidney, both of which arose from the hilum and entered the vena cava.

Case XVIII. The right kidney possessed two small renal arteries coming directly from the aorta and entering the kidney at the hilum. The left kidney as well as the veins were normal.

Case XIX. Both kidneys possessed three renal arteries rather small in size, which entered the kidney at the hilum. The veins were normal.

Case XX. The right kidney was normal. The left possessed two renal arteries, both of which were branches of the aorta, and entered the kidney at the hilum. The veins were normal.

Case XXI. The right kidney possessed two renal arteries, one of which entered the superior, the other the inferior pole. The left kidney possessed three renal arteries, which arose from the aorta as separate branches, and entered the kidney at the hilum. The veins were normal.

Case XXII. The right kidney possessed three renal arteries, arising from the aorta and entering the kidney from the hilum. The left kidney possessed two renal arteries, one arising from the aorta and entering the kidney at the hilum, the other arising from the coeliac axis and entering the kidney at the superior pole 2 cm. from the upper border. The veins were normal.

The embryological origin of the renal arteries has not yet been satisfactorily explained. The explanation as here offered is after Keibel and Mall.

His ('80) first observed multiple branches of the aorta supplying the mesonephros in 7 mm. embryos. A more extended account of them has been given by Broman. At first, when the Wolffian bodies are relatively small, the mesonephric vessels are correspondingly small. They come from the middle portion of the aorta (2nd to 8th thoracic). At the end of the first month the mesonephros reaches its greatest development. It receives many direct branches from the aorta at levels cranial as well as caudal to the original ones. In 8 mm. embryos there are twenty mesonephric arteries on each side (8 cervical to 12th thoracic segments). The last vessels to appear grow out from the region between the first and second lumbar segments. These are destined to persist as the remainder atrophy. There are then on each side—in maximo—thirty vessels distributed throughout the entire mesonephric area. At first these are entirely distributed to the mesonephros, but later also supply the reproductive glands, suprarenal bodies, metanephroi, and diaphragm. These new regions of distribution prevent their com-

plete degeneration when the mesonephros disappears. A variable number of them persist as phrenic, suprarenal, renal, accessory renal, internal spermatic, accessory spermatic arteries, and as the rami ad lympho-glandulas and ad sympatheticum. The first mesonephric arteries found in embryos 5.3 mm. arise from the lateral surface of the aorta, and pass horizontally to the urogenital fold, reaching the malpighian corpuscles, and terminating in them with an enlargement which usually assumes a spherical shape. Later a network of vessels occupies the place of the enlargement. This network is also connected with the

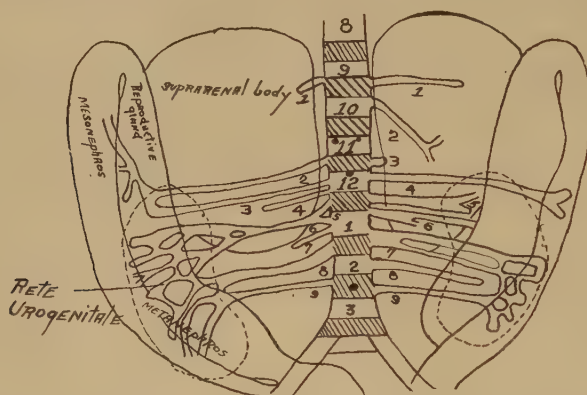


Fig. 1 Mesonephric arteries in human embryo of 18 mm. greatest length. Circles on anterior surface of aorta indicate origin of coeliac, superior and inferior mesenteric arteries (after Keibel and Mall).

posterior cardinal vein. Case IX is an example of the persistence of this anastomosis. With increasing age the arteries continually recede into the lumbar segments disappearing from the thoracic ones.

The arteries are divided into three groups by the suprarenal body: the cranial group, which is dorsal to the suprarenal (1-2); the middle group, whose vessels pass through the suprarenal (R. 3-4, L. 3-5); and the caudal group whose vessels pass over the ventral side of the suprarenal body (R. 5-6, L. 6-9). The mesonephric arteries (5-9) situated in the angle formed by the reproductive gland ventrally, the mesonephros laterally, and the

metanephros dorsally, form a network: the rete arteriosum urogenitale. The mesonephros, reproductive gland, and the metanephros are supplied with arterial branches from this network, thus making these organs independent of single branches for their blood supply. Should one or several roots degenerate, neighboring arteries can take their places. In the above diagram, for instance, the second mesonephric artery has divided into an ascending and descending branch; the ascending one supplies the entire upper half of the mesonephros and the reproductive gland, a region that in the young embryo receives its blood from several mesonephric arteries belonging to more cranial segments. The occurrence of this network at once explains why all persistent arteries that arise from the roots of this network show, within certain limits a variability in the points of their origin from the aorta. Each of the nine to eleven remaining mesonephric arteries may become an internal spermatic artery, since all supply the reproductive glands. This explains the frequently observed multiplicity of these arteries, and the not infrequent difference in the place of origin of the right and left ones.

The renal arteries are not new formations, as some have claimed, but each is formed from a mesonephric artery. The kidney climbs upward to the mesonephric artery and as soon as sufficient blood supply is assured cranially, the caudal branches separate from it. When the kidney has acquired its definitive position it possesses several arteries, and of these one becomes greatly enlarged to form the definitive artery, while the others either degenerate, or persist as accessory renals. The definitive renal artery is either the last vessel of the second group, or first of the third group. The relations of both groups, i.e., of the second to the suprarenal artery, and of the third to the internal spermatic, explain the variation in which the renal artery arises from a suprarenal or from an internal spermatic. In the first case it may be the principal stem; in the latter, only an accessory renal. The relations between the urogenital rete and metanephros show how the accessory renal arteries may develop, and explain their varied relations to the kidney. Accessory renal

arteries from the first group will be branches of the superior suprarenal, and must pass over the dorsal surface of the kidneys. These consequently first reach the kidney on its dorsal surface and there penetrate its cortex. Those from the second group will be branches of either the middle or inferior suprarenal, and will reach either the hilus or the kidney or the medial edge above this. Those from the third group may enter the hilus at the medial edge below it, or on the ventral surface of the caudal half of the organ. Should a caudal branch be retained, it will be drawn upwards by the migration of the kidney. This condition explains why such an artery may cross the principal stem or another accessory.

Anomalous renal vessels are not only interesting from a purely scientific point of view, but are also of very great significance from a clinical and surgical standpoint.

The Mayos in 20 out of 27 cases operated upon by them for hydronephrosis, found anomalous blood vessels. The obstruction in each case was caused by the blood vessel crossing the uretero-pelvic juncture. The vessels passed to the lower pole of the kidney, and varied from the size of a knitting needle to that of the radial artery.

Levings, in a report of four cases on which operations were performed, found anomalous arteries which crossed the ureter, and to which condition he attributed the clinical symptoms of the patients. He also reported post-operative improvement in every case.

Rupert in 1913 found anomalous renal vessels in 35 out of 50 cadavers studied. In every case the kidneys were normally placed, and of normal size and shape. He concluded that the usual percentage given is too low, and that anomalous renal veins, while not as common as the arteries, do occur, and that on account of the thinness of their walls and lack of pulsations they increase the hazards of kidney operations.

It is very evident from the specimens at hand that a number of these arteries might be overlooked if it were necessary to remove or examine any of these kidneys. In view of the fact that anomalous renal arteries are important it is rather strange



that their existence has been neglected in surgical anatomy teaching. As Rupert points out, the most common text books of anatomy and surgery make but brief mention of this condition, and some do not even refer to it at all.

The accepted percentage of 20 to 25 as given by Quaine and Gerrish is evidently too low. Senator as recently as 1905 made the statement that "Reduplications of one or both renal arteries is a rare condition and may be dismissed." Rupert found 35 cases or 70 per cent of anomalous renal vessels, while in this present investigation there are 22 cases out of 33, or 73 per cent. In all of these cases the kidneys were normally placed and the anomalous arteries were so arranged that they would easily complicate surgical procedures.

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SIZE AND LENGTH RELATIONS OF THE RIGHT AND LEFT TESTES OF PIGEONS IN HEALTH AND DISEASE

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The right ovary undergoes an early and more or less complete atrophy in most species of birds. Etzold ('91) has shown that in the sparrow the left testis is larger than the right. Firket ('14) and Swift ('15) have shown that in the chick embryo there were more primordial germ cells in the left gonad, and that this gonad is there also distinctly larger than the right. Allen ('07) found that the sex cells were unequally distributed to the two gonads of the turtle, the left receiving most. In this form only 24-70 per cent of the sex cells ever enter the gonads. Our own accumulation of data on the size and length relations of the two testes of young and adult pigeons show a very decided predominate number of larger right testes; and also a distinct difference in shape of the two glands—the left though actually smaller in size is usually absolutely longer than the right. Changes in the size relation in birds dead of certain diseases—particularly tuberculosis—and in hybrids are also suggested by our data

The meaning of this pronounced inequality in the distribution of the primordial germ cells which is plainly associated with a larger left embryonic gonad, and the finding in adults of two groups of birds of a marked and nearly constant larger gonad, but this a different gonad in the two cases, is by no means clear. But, whatever this may mean, it is probably a situation of importance to the theory of sex. We present our present data then with the confession that on the main points the meaning is not clear, but with the conviction that they are not less valuable because of our present inability to clarify the puzzling situation, and hopeful that the data may stimulate the further

accumulation of facts from enough forms, and of such varied kinds, as may lead to a better understanding of the embryonic and adult inequalities of the sex glands of birds.

An examination of our data has shown that the measurements of glands of healthy birds should be grouped apart from those dead of disease; and those of pure species should be separated from hybrids. The justification of these separate groupings will appear later.

The relative size of the sex glands in healthy common pigeons

The weights of 31 pairs of testes from healthy common pigeons are recorded in table 1. In 27 of these pairs the left testis was the smaller; in 4 the left was the larger. In two or three of these latter cases—12, 15 (22?)—the disparity of the two glands is so great as to make it clear that the smaller gland was wholly abnormal. In healthy common pigeons the right testis is larger than the left in a high proportion of cases.

Size relations of the testes of common pigeons dead of disease

In tables 2 and 6 the weights of 9 pairs of testes are given. In 7 of these the left gland was the smaller. It was larger in two instances; in one of these irregular cases, the smaller gland was again quite abnormally proportioned in reference to its larger associate

Size relations of testes of pure species, healthy and dead of disease

The testes of only 5 healthy birds of pure species (dead of cold, exposure, accident) are included in table 6. In all of these cases the right testis was the larger.

The data for 46 individuals of pure species dead of disease are available. In table 2, 9 of the 10 individuals listed had larger right testes; the tenth had the two glands of equal size. Eleven further comparisons are supplied in table 3. Of these, 7 right testes are larger, 2 are smaller, and 2 are the size-equivalents of the left. Table 6 gives the data for 30 additional pairs. Of these, 7 of *St. risoria* all had larger right testes; 2 of *T. orientalis* both had larger right testes; 13 of *Spil. tigrina*—mostly not

mature birds had, 5 larger, 5 smaller, and 3 equivalent right testes. Four miscellaneous birds here had 2 larger and 2 smaller¹ right testes.

TABLE 1
Weight of right and left testes of healthy common pigeons

NO.	DATE	WEIGHT	PER CENT OF DIFF.	NO.	DATE	WEIGHT	PER CENT OF DIFF.
1	April 5.....	R = 0.885 L = 0.515	-71.8*	17	April 9.....	R = 1.115 L = 1.015	-9.9
2	April 5.....	R = 1.475 L = 0.845	-74.6	18	July 5.....	R = 1.010 L = 0.750	-34.7
3	April 5.....	R = 1.185 L = 0.990	-19.7	19	July 5.....	R = 1.220 L = 1.375	+12.7
4	April 5.....	R = 1.055 L = 0.820	-28.7	20	July 5.....	R = 1.140 L = 0.970	-17.5
5	April 7.....	R = 1.410 L = 0.765	-84.3	21	July 5. . . .	R = 1.158 L = 0.765	-51.4
6	April 7.....	R = 1.190 L = 0.975	-22.1	22	July 5.....	R = 0.370 L = 0.720	+94.6
7	April 7.....	R = 1.260 L = 1.000	-26.0	23	July 9.....	R = 0.855 L = 0.800	- 6.9
8	April 7.....	R = 1.235 L = 0.945	-30.7	24	July 9.....	R = 1.643 L = 1.030	-59.5
9	April 7.....	R = 1.280 L = 1.225	- 4.5	25	July 13.....	R = 0.571 L = 0.540	- 5.7
10	April 9.....	R = 1.075 L = 0.900	-19.4	26	July 13.....	R = 0.820 L = 0.631	-29.9
11	April 9.....	R = 1.025 L = 0.710	-44.4	27	July 16.....	R = 1.820 L = 1.500	-21.3
12	April 9.....	R = 0.025 L = 0.715	+2760.0	28	July 18.....	R = 1.600 L = 0.536	-198.5
13	April 9.....	R = 1.460 L = 1.390	- 5.0	29	July 20.....	R = 0.051 L = 0.040	-27.5
14	April 9.....	R = 1.010 L = 0.720	-40.3	30	July 20.....	R = 1.390 L = 1.085	-28.1
15	April 9.....	R = 0.275 L = 1.425	+418.2	31	July 21 (juv.)	R = 0.0004 L = 0.0003	-33.3
16	April 9.....	R = 1.125 L = 0.500	-125.0	Left smaller in 27; larger in 4.			

* In calculating percentage differences in these tables the smaller gland is considered as equal to 100 per cent.

¹ In both of these cases where the right testes weighed less than the left it will be seen that both testes were quite small—so small as perhaps to raise a question as to the reliability of the weights.

Size of testes in healthy specific hybrids

In tables 4 and 5 the data for 30 healthy young hybrids are given. The very small gonad size of most of these young birds

TABLE 2
Weights of right and left testes of various pigeons (classified) dead of disease

NO.	DATE	WEIGHT	PER CENT OF DIFF.	NO.	DATE	WEIGHT	PER CENT OF DIFF.
1. Common pigeons							
32	July 28.....	R = 0.122 L = 0.460	+277.0	34*	September 28	R = 0.037 L = 0.034	-8.8
33*	September 1.	R = 0.580 L = 0.415	-39.8	35	December 14.	R = 1.300 L = 0.850(?)	-52.9
2. Blond and white wing doves and their hybrids							
Hybrids, (specific)				Pure			
36*	June 10.....	R = 0.417 L = 0.305	-36.7	42*	April 9.....	R = 0.045 L = 0.025	-80.0
37*	June 27.....	R = 0.050 L = 0.035	-42.9	43*	April 17.....	R = 0.060 L = 0.050	-20.0
38*	July 23....	R = 0.032 L = 0.046	+43.8	44*	September 26	R = 0.055 L = 0.055	0.0
39	September 12	R = 0.765 L = 0.705	-8.5	45*	October 25...	R = 0.068 L = 0.056	-21.4
40	October 17..	R = 0.0053 L = 0.0067	+26.4	46	October 25..	R = 0.046 L = 0.033	-39.3
41*	October 31...	R = 0.090 L = 0.090	=0.0	47*	October 28...	R = 0.030 L = 0.027	-11.1
3. Other hybrids (specific, ex. 51, 52 = gen.)							
48	August 28....	R = 0.845 L = 0.600	-40.8	51*	September 18.	R = 0.580 L = 0.510	-13.7
49	June 10.....	R = 0.190 L = 0.160	-18.8	52	September 23.	R = 0.040 L = 0.031	-29.0
50	August 28....	R = 0.133 L = 0.115	-15.7	53*	September 27.	R = 0.010 L = 0.012	+20.0
4. Other pure species							
54*	August 26....	R = 0.040 L = 0.022	-81.8	56	October 31...	R = 0.465 L = 0.445	-4.5
55*	November 10	R = 0.033 L = 0.023	-43.5	57*	November 9..	R = 0.015 L = 0.013	-15.4

* Tuberculosis found.

TABLE 3.

Weights of testes of doves (classified) dead of disease March 29 to November 25, 1915

NO.	DATE	WEIGHT	PER CENT OF DIFF.	NO.	DATE	WEIGHT	PER CENT OF DIFF.
Pure species				Specific hybrids			
59*	March 29....	R = 0.012 L = 0.018	+50.0	76*	May 1.....	R = 0.030 L = 0.031	+ 3.3
60*	April 1.....	R = 0.008 L = 0.005	-60.0	77*	July 23.....	R = 0.262 L = 0.212	-23.6
61*	April 2.....	R = 0.105 L = 0.105	= 0.0	78*	July 30.....	R = 0.040 L = 0.032	-25.0
62*	April 16.....	R = 0.022 ¹ L = 0.060	+172.7	79*	August 22....	R = 0.076 L = 0.077	+ 1.3
63	September 2.	R = 0.158 ² L = 0.146	- 8.2	80	August 29....	R = 0.605 ² L = 0.454	-33.3
64*	September 5..	R = 0.032 L = 0.020	-60.0	81*	September 19	R = 0.188 L = 0.152	-23.7
65	September 11 (Juv.).....	R = 0.003 L = 0.002	-50.0	82*	September 28	R = 0.026 L = 0.026	=0.0
66*	September 14	R = 0.023 L = 0.023	= 0.0	83*	October 7....	R = 0.025 L = 0.021	-19.0
67*	September 29	R = 0.138 L = 0.116	-18.9	84*	October 19 (Juv.).....	R = 0.007 L = 0.006	-16.6
68*	October 3....	R = 0.045 L = 0.030	-50.0	85*	October 24...	R = 0.030 L = 0.030	- 0.0
69*	November 11.	R = 0.082 L = 0.067	-22.4	86*	November 21 (Juv.).....	R = 0.015 L = 0.020	+33.3
Generic hybrids				87*	November 22.	R = 0.014 L = 0.016	+14.3
70*	April 2.....	R = 0.140 L = 0.125	-12.0	88	November 25.	R = 0.018 L = 0.015	-20.0
71*	May 30.....	R = 0.320 L = 0.280	-14.3	Common pigeons			
72	June 20.....	R = 0.082 L = 0.076	- 7.9	89	April 28.....	R = 1.260 L = 1.035	-21.7
73*	July 16.....	R = 0.300 L = 0.298	- 0.7	90*	August 25....	R = 0.098 L = 0.087	-12.6
74*	August 2.....	R = 0.012 L = 0.010	-20.0	91	April 5.....	R = 1.105 ³ L = 0.990	-11.6
75*	August 17....	R = 0.040 L = 0.037	- 8.1				

* Tuberculosis found.

¹ The left suprarenal wholly involved in a tubercle nodule weighing nearly 1.0 gr.² Healthy.³ A hybrid from a family cross.

TABLE 4

Weight, length and width of testes of young Ring dove (specific) hybrids—killed

NO.	DATE	WEIGHT	PER CENT OF DIFFER- ENCE	LENGTH AND WIDTH	PER CENT OF DIFFER- ENCE
88a	December 4, 1915..	R = 0.035 L = 0.030	-16.7	8.0 x 3.8	
89a	December 4, 1915..	R = 0.007(?) L = 0.005(?)	-40.0	5.1 x 1.6 .6 x 1.4	-10.9
90a	December 4, 1915..	R = 0.004(?) L = 0.005(?)	+25.0	4.1 x 0.9 4.9 x 0.9	+19.5
91a	December 4, 1915..	R = less than 0.005(?) L = 0.005(?)	+?	5.1 x 0.8 5.1 x 1.5	=0.0
92	December 4, 1915..	R = 0.005(?) L = 0.005(?)	= 0.0	4.8 x 1.5 5.3 x 1.4	+10.4
93	December 4, 1915..	R = 0.007(?) L = 0.005(?)	-40.0	4.8 x 1.6 5.3 x 0.9	+10.4
94	December 4, 1915..	R = 0.015 L = 0.010	-50.0	6.6 x 1.9 6.6 x 1.5	=0.0
95*	December 8, 1915..	R = 0.025 L = 0.025	= 0.0	8.3 x 2.2 9.0 x 1.9	+8.4
96	December 8, 1915..	R = 0.037 L = 0.025	-48.0	8.4 x 2.7 7.2 x 2.2	-16.7
97	December 8, 1915..	R = 0.010 L = 0.007	-42.9	5.0 x 1.8 5.0 x 1.5	=0.0
98	December 8, 1915..	R = 0.320 L = 0.280	-14.3		
99	December 8, 1915..	R = 0.007(?) L = 0.005(?)	-40.0	4.4 x 1.7 5.0 x 1.0	+13.6
100	December 8, 1915..	R = 0.025 L = 0.020	-25.0	6.8 x 2.2 6.7 x 2.1	-1.5
101	December 8, 1915..	R = 0.010 L = 0.007	-42.9	6.5 x 1.9 6.5 x 1.5	=0.0
102	December 8, 1915..	R = 0.012 L = 0.012	= 0.0		
103	December 8, 1915..	R = 0.035 L = 0.025	-40.0		
104	December 8, 1915..	R = 0.100 L = 0.070	-42.9		
105	December 8, 1915..	R = 0.017 L = 0.015	-13.3		
				Summary:	
				Left larger in.....	2
				Left smaller in....	13
				Two equal in.....	3
				Left longer in....	5
				Left shorter in....	3
				Left equal in.....	4

* Tuberculosis found.

is probably responsible for the failure of our weighings to differentiate between the masses of several pairs of the testes. In the 30 pairs 18 right testes were larger, 5 were smaller, 7 were not differentiated by the weighings.

Size of testes in hybrids dead of disease

Seven of the 10 specific hybrids of table 2 had larger right testes; 2 had smaller; 1 had the testes of equal size. Of the two generic hybrids (52, 53) represented in this table, one had a larger and one a smaller right testes. In table 3 are listed 13 specific hybrids; 7 larger right testes, 4 smaller, and 2 equivalents.

TABLE 5

Weight, length and width of testes of young Ring dove (specific) hybrids—killed

NO.	DATE	WEIGHT	PER CENT OF DIFFER- ENCE	LENGTH AND WIDTH	PER CENT OF DIFFER- ENCE
106	November 29, 1915	R = too small to weigh		3.2 x 1.5	
		L = 0.005	+ 7.0	4.7 x 1.8	+46.9
107	November 29, 1915	R = 0.007		5.8 x 1.6	
		L = 0.007	= 0.0	5.4 x 2.0	- 7.4
108	November 29, 1915	R = 0.009		5.8 x 1.8	
		L = 0.010	+11.1	6.4 x 1.8	+10.3
109	November 29, 1915	R = 0.020		8.2 x 1.9	
		L = 0.019	- 5.3	8.2 x 1.9	= 0.0
110	November 29, 1915	R = 0.018		7.4 x 2.0	
		L = 0.020	+11.1	7.4 x 2.0	= 0.0
111	November 29, 1915	R = 0.010		5.9 x 2.2	
		L = 0.010	= 0.0	7.4 x 1.6	+25.4
112	November 29, 1915	R = 0.190		17.0 x 4.5	
		L = 0.170	-11.8	15.7 x 4.5	- 8.3
113	December 3, 1915..	R = 0.007		5.7 x 1.5	
		L = 0.005	-40.0	4.9 x 0.9	-16.3
114	December 3, 1915..	R = 0.007		5.5 x 1.4	
		L = 0.005	-40.0	4.2 x 1.0	-30.9
115	December 3, 1915..	R = 0.007		Summary: Left larger in..... 3 Left smaller in..... 5 Two equal in..... 4 Left longer in..... 3 Left shorter in..... 4 Two equal in..... 2	
		L = 0.007	= 0.0		
116	December 3, 1915..	R = 0.005			
		L = 0.005	= 0.0		
117	December 3, 1915..	R = 0.007			
		L = 0.005	-40.0		

TABLE 6

Weights and measurements of testes—birds classified as to kind and disease

NO.	DATE	DISEASE ¹	WEIGHTS	PER CENT OF DIFFERENCE	LENGTH AND WIDTH	PER CENT OF DIFFERENCE
Pure species— <i>Spil. tigrina</i>						
118	January 7	Worms	R = 0.050 L = 0.050	= 0.0	7.8 x 3.4 10.8 x 3.0	+38.5
119	January 9	Worms (juv.)	R = 0.012 L = 0.014	+16.6	5.3 x 2.2 7.0 x 1.8	+32.1
120	January 11	Liver	R = 0.040 L = 0.045	+12.5	7.3 x 3.0 9.0 x 2.8	+23.3
121	January 11	Liver and worms ..	R = 0.055 L = 0.055	= 0.0	8.3 x 3.2 8.3 x 3.0	= 0.0
122	January 13	Worms	R = 0.080 L = 0.080	= 0.0	9.3 x 4.5 10.6 x 4.3	+13.9
123	January 15	Worms liver	R = 0.040 L = 0.045	+12.5	6.5 x 3.0 8.2 x 2.8	+26.2
124	January 18	Intest. and liver ..	R = 0.031 L = 0.027	-14.8	5.1 x 3.4 6.7 x 2.7	+31.4
125	January 25	Intest.	R = 0.030 L = 0.045	+16.6	7.1 x 3.0 8.6 x 3.1	+21.1
126	January 29	Worms (old)	R = 0.030 L = 0.022	-36.4	7.6 x 2.6 7.0 x 2.3	- 8.6
127	March 1	Intest. (juv.)	R = 0.004† L = 0.004-	- ? 0	4.2 x 2.1 4.4 x 1.9	+4.8
128	May 17	Sp. Li. (old)	R = 0.047 L = 0.035	-34.3	8.7 7.2	-20.8
129	January 28	Liver and spleen ..	R = 0.030 L = 0.025	-20.0	6.8 x 3.1 7.2 x 2.4	+ 5.9
130	January 28	Worms	R = 0.027 L = 0.030	+11.1	6.7 x 2.5 8.8 x 2.5	+31.3
Pure species— <i>T. orientalis</i>						
131	March 8	Lu. liver	R = 0.016 L = 0.015	- 6.6		
132	March 23	Cold (juv.)	R = 0.010 L = 0.008	-25.0	5.4 x 1.5 3.7 x 1.7	-45.9
133	March 23	Cold (juv.)	R = 0.010 L = 0.008	-25.0	6.0 x 1.4 4.7 x 1.7	-27.6
134	March 23	Cold (juv.)	R = 0.011 L = 0.009	-22.2	7.0 x 1.4 6.3 x 1.5	-11.1
135	March 25	Intest. (juv.)	R = 0.010 L = 0.007	-42.9	5.8 x 1.9 5.5 x 1.6	- 5.5

¹ Abbreviations of the names of organs to their first two letters, implies that advanced and very evident tuberculosis was found in those organs (lungs, spleen, liver, joints, mesentery, intestine). Where more than one organ was affected the name of the organ (or organs) apparently most affected is written first. When the word is written out it denotes that this organ was abnormal, but not necessarily tubercular; immature birds are designated—(juv.).

TABLE 6—Continued

NO.	DATE	DISEASE	WEIGHTS	PER CENT OF DIFFER- ENCE	LENGTH AND WIDTH	PER CENT OF DIFFER- ENCE
Pure species— <i>St. risoria</i>						
136	December 4	Sp. li. lu.....	R = 0.030 L = 0.025	—20.0		
137	January 29	Sp. lu. li.....	R = 0.053 L = 0.031	—70.9	9.2 x 3.3 10.5 x 1.9	+14.1
138	January 29	Sp. lu. li.....	R = 0.015 L = 0.010	—50.0	6.0 x 2.3 6.6 x 2.0	+10.0
139	February 4	Intest.....	R = 0.037 L = 0.020	—85.0	8.4 x 2.9 8.8 x 2.3	+ 4.8
140	March 15	Lu. (?) liver.....	R = 0.550 L = 0.401	—37.1		
141	May 10	Sp.....	R = 0.023 L = 0.019	—21.1	8.0 8.0	= 0.0
142	May 14	Jo., lu. sp.; liver...	R = 0.020 L = 0.017	—17.6	6.7 6.9	+ 2.9
Miscellaneous—pure species						
143	November 17	Canker, li., sp. lu..	R = 0.010 L = 0.007	—42.9		
144	November 17	Fight and hemorr..	R = 0.595 L = 0.475	—25.3		
145	November 18	Unknown (juv.)....	R = 0.0038 L = 0.0042	+10.5		
146	November 20	Cold (?).....	R = 0.165 L = 0.127	—29.9		
147	December 3	Liver.....	R = 0.015 L = 0.016	+ 6.7		
Common pigeons						
148	January 3	Unknown (juv.)....	R = 0.005(?) L = 0.005(?)		5.4 x 1.5 5.2 x 1.3	— 3.8
149	January 17	Unknown (juv.)....	R = 0.009(?) L = 0.010(?)	+11.1	5.8 x 1.5 6.5 x 1.7	+12.1
150	February 15	Li. pleura.....	R = 0.004? L = 0.003?	—33.3?	about 6.0 mm. long about 5.3 mm. long	+13.2
151	April 13	Hemorrhage, liver..	R = 0.014 L = 0.010	—40.0	6.4 6.4	= 0.0
152	April 17	Appar. healthy....	R = 1.340 L = 1.315	— 1.1	20.2 x 12.1 23.9 x 10.7	+18.3
153	May 4	Weakling (juv.)....	R = 0.006 L = 0.004	—50.0	5.2 5.2	= 0.0

TABLE 6—Continued

NO.	DATE	DISEASE	WEIGHTS	PER CENT OF DIFF- ERENCE	LENGTH AND WIDTH	PER CENT OF DIFFER- ENCE
Hybrids—from crosses of species						
154	January 1	Cold? (juv.).....	R = 0.000 L = 0.000		4.2 x 0.9 5.2 x 1.2	+23.8
155	January 4	Sp. liver.....	R = 0.014 L = 0.017	+21.4	6.3 x 2.1 8.6 x 2.5	+36.5
156	January 8	(Juv.).....	R = 0.000 L = 0.000		3.8 x 1.5 5.7 x 1.2	+50.0
157	January 15	Lu.....	R = 0.037 L = 0.035	- 5.7	8.7 x 2.7 8.4 x 2.8	- 3.6
158	December 3	Li. (juv.).....	R = 0.003 L = 0.003	= 0.0		
159	January 15	Sp. jo.....	R = 0.027 L = 0.020	-35.0		
160	January 27	Healthy dwarf; killed.....	R = 0.010(?) L = 0.013(?)	+30.0?		
161	February 18	Sp. lu.....	R = 0.015 L = 0.015	= 0.0		
162	March 6	Sp. li., etc.....	R = 0.028 L = 0.025	-12.0		
163	January 22	Li., sp.....	R = 0.007 L = 0.007	= 0.0	5.0 x 2.1 5.6 x 2.0	+12.0
164	January 24	Lu., liver, spleen...	R = 0.050 L = 0.050	= 0.0	9.7 x 2.9 10.4 x 2.7	+ 7.2
165	January 27	Liver, lu. (?).....	R = 0.052 L = 0.050	- 4.0	9.0 x 3.7 11.4 x 2.9	+26.6
166	February 13	Lu., liver, spleen (juv.).....	R = 0.002? L = 0.003+	+50.0	5.7 5.9	+ 3.5
167	March 17	Sp., lu. liver.....	R = 0.022 L = 0.021	- 4.7		
168	March 18	Sp. li., lu.....	R = 0.025 L = 0.025	= 0.0	7.2 7.6	+ 5.6
169	March 26	Intest. (?) (juv.)...	R = 0.002 L = 0.002	= 0.0	4.4 3.9	-12.8
170	March 28	Sp. me. lungs.....	R = 0.048 L = 0.042	-14.3	9.9 x 3.7 10.1 x 2.3	+ 2.0
171	March 29	Li. sp., me.....	R = 0.031 L = 0.035	+12.9	8.7 x 2.9 12.2 x 2.2	+40.2
172	April 12	Cold, lungs.....	R = 1.015 L = 0.888	-14.3	22.6 x 9.0 23.5 x 8.2	+ 3.9
173	April 20	(Juv.).....	R = 0.002(?) L = 0.002(?)	= 0.0	5.2 5.4	+ 3.8

TABLE 6—Continued

NO.	DATE	DISEASE	WEIGHTS	PER CENT OF DIFF- ERENCE	LENGTH AND WIDTH	PER CENT OF DIFFER- ENCE
Hybrids—from crosses of species (con.)						
174	April 23	Liver (intest. ?)....	R = 0.054 L = 0.044	-22.7	10.8 10.6	- 1.9
175	May 6	Sp. li. pe.....	R = 0.034 L = 0.032	- 6.3	8.2 8.2	= 0.0
176	May 6	Sp.....	R = 0.020 L = 0.022	+10.0	7.6 8.0	+ 5.3
177	May 10	Li. spleen.....	R = 0.042 L = 0.036 ⁴	-16.7	8.3 8.7	+ 4.8
178	May 11	Sp. li.....	R = 0.021 L = 0.018	-16.7	7.2 6.6	- 9.1
179	May 16	Healthy (juv.).....	R = 0.125 L = 1.25	= 0.0	11.6 x 4.5 13.2 x 4.3	+13.8
Hybrids—from crosses of genera						
180	December 4	Sp., li.....	R = 0.017 L = 0.020	+17.6	7.0 x 2.0 6.3 x 2.5	-11.1
181	December 24	Liver, pericard.....	R = 0.017 L = 0.020	+17.6		
182	January 8	Cold (?).....	R = 0.005 L = 0.004	-25.0	3.2 x 1.8 3.0 x 1.5	- 6.6
183	January 12	Abdom. wall.....	R = 0.009 L = 0.012	+33.3	7.3 x 1.8 5.7 x 1.9	-28.1
184	February 8	Intest.....	R = 0.005? L = 0.004?	-25.0	about 4.5 about 4.5	= 0.0
185	February 23	Intest. (?).....	R = 0.045 L = 0.051	+12.3	7.3 7.1	- 0.3
186	March 7	(Cold?) lungs.....	R = 0.007 L = 0.005	-40.0	{ both testes an- gular-globular, like hemip seed	
187	March 13	Li., sp., lu. (?).....	R = 0.014 L = 0.019	+35.7	7.0 9.0	+28.5
188	March 29	(Cause?).....	R = 0.006 L = 0.007	+16.7	4.6 x 1.9 5.3 x 2.0	+15.2
189	April 12	Worms, fighting....	R = 0.256 L = 0.212	-20.8	15.7 x 5.6 15.4 x 5.1	- 1.9
190	May 15	Lu.....	R = 0.047 L = 0.043	- 9.3	8.8 x 8.0 x	-10.0

Six generic hybrids here all show larger right testes. Of 24 birds listed in table 6, larger rights were found in 11, smaller in 5, equivalents in 8 cases. In table 6, 11 generic hybrids are listed; the right testis is larger in 5, smaller in 6.

A summary representation of the weight relations of the testes of birds belonging to the several preceding groups is given in table 7.

Relative lengths of the two testes

The length of 78 pairs of testes was ascertained. These were obtained from the testes of birds belonging to all of the groups discussed in the previous section of this paper. The reader is referred to the summary on 'length relations' given in table 7 for a first view of the result. Although a high proportion (126 to 39 for all groups) of the right testes are heavier, a reversal of proportions (24 to 42) is found for the absolute lengths of the two testes. In five of the seven groups of table 7 the left testis is absolutely longer. In one of the two exceptional groups—

TABLE 7
Summary of the preceding data

CLASS	STATE	WEIGHT RELATIONS ¹			LENGTH RELATIONS		
		L +	L =	L -	L +	L =	L -
Pure species.....	Healthy...	0	0	5	0	0	3
	Diseased...	9 ²	7 ²	31	14	2	2
Common pigeons.....	Healthy...	5	0	27	1	0	0
	Diseased...	2	0	8	2	2	1
Specific hybrids.....	Healthy...	6	7	19	8	6	7
	Diseased...	10	11	24	15	1	4
Generic hybrids.....	Diseased...	7	0	12	2	1	6
Total healthy.....		11	7	51	9	6	10
Total diseased.....		28	18	74	33	6	14
Grand total.....		39	24	126	42	12	24

¹ The cases of larger left testis, are grouped under L+; those of equal size under L=; those with a smaller left testis under L-.

² Five of the (9), and 3 of the (6), are from 14 *Sp. tigrina*—all dead at less than 9 months old.

'healthy pure species'—it is possible that the smaller length of the left testis is connected with the nearest approximation to uniformity of smaller size in this group. In the second group—'diseased generic hybrids'—the testes show the greatest departure in their weight relations from what is elsewhere the rule.

An examination of the detailed measurements and percentage weight differences given in tables 4, 5 and 6 is even more convincing than the summary of table 7 on the point that the two testes definitely tend to assume two different shapes—the left to be thinner and more elongate, the right to be shorter and thicker. This difference in form is perhaps not without interest since the only persistent gonad in the female—that of the left side—is characteristically 'thin' and 'long.' The testis that develops on this side is similarly characterized as compared with its mate of the right side.

Pure species and hybrids and the relative size of the two testes

Table 7 facilitates an expression of a relation which seems to obtain between degree of hybridization on the one hand, and the number of departures from the usual situation—a larger right and a smaller left testis—on the other. There are good reasons for believing that common pigeons—mongrels of many breeds probably not even descended from a single good species—may rightly occupy a place in this classification intermediate to specific hybrids and pure species. There is no question that the generic hybrids are more separated from the pure species than are the specific hybrids. Now, the number of gonad size relations, that depart from the rule, arrange themselves in all of the seven groups of the table, precisely in this order of departure from purity of species. That is, the greatest proportion of larger left testes is found in the group most widely separated from a pure species (generic hybrids); and the two intermediate stages of crossing (specific hybrids and common pigeons) show each its appropriately smaller intermediate number of larger left testes.

The influence of disease on the actual and relative size of the two testes

The detailed data of the several tables and the summary of table 7 demonstrate that diseased birds furnish a higher proportion of larger left testes—violations of the more general rule—than do healthy birds. Further, the testes of pigeons suffer great reduction in several, or most, forms of disease. Now it probably happens that because of the great reduction in size of the testes in disease that this of itself has rendered the results of a few of the weighings of the smallest glands less certain.¹ An examination of the detailed data will, however, leave no doubt that disease is a very real and important reason for the observed differences.

It has been found well to designate the cause of death in most of the tables. Advanced tuberculosis is easily, and with much certainty, diagnosed in pigeons. It is the most common cause of death among the birds of our collection. All deaths from this cause are so designated in the tables. A careful comparison of the size of the testes of birds dead of tuberculosis as compared with those dying of other or unknown causes will show that the gonads of the male suffer greatest reduction under this disease. This is certainly not true for the female gonad; a point upon which data are still being collected. In this connection Hatai's ('15) observation of the effects of exercise on the size of the ovary and testis of the rat are of interest. Hatai found a like qualitative response—an increase—in both; but quantitatively the response was quite different; the testes increased only 12.33 per cent while the increase in the ovaries was 84.33 per cent.

The several sections of table 6 show that in pigeons the spleen and liver are more often affected by tuberculosis than are other organs. It is the spleen too that suffers greatest hypertrophy and most complete transformation under the disease. This is true of both sexes.

¹ Because of imperfect or unclean separation of the gland from body wall, and drying during weight, the greatest care will not always obtain perfect weights of the smallest of these glands.

Size relations of the testes in the common fowl

In table 8 are given the few data we have been able to obtain on the Jungle fowl, common fowl, and the duck. Since these were—with two exceptions—healthy fowls even the few data indicate a situation different from that found in pure species of pigeons. Whether these data are really representative of these forms, cannot now be determined. Whether hybridization (or mongrelization) of these forms is responsible for the apparent predominance of the reverse of the situation found in pigeons is doubtful. They like the sparrows may normally possess a larger left and a smaller right testis.

TABLE 8
Weights of testes of Jungle Fowl and common fowl

NO.	DATE	WEIGHT	PER CENT OF DIF- ERENCE	NO.	DATE	WEIGHT	PER CENT OF DIF- ERENCE
Jungle fowl				Common fowl			
1	July 5	R = 3.203 L = 4.217	+31.7	1	July 16	R = 3.734 L = 4.219	+12.9
2	July 5	R = 4.700 L = 5.700	+21.3	2	July 16	R = 5.880 L = 7.000	+19.0
3	July 8	R = 4.635 L = 4.280	- 8.4	3	July 20	R = 6.540 L = 5.610	-16.6
4	July 10	R = 6.305 L = 6.270	- 0.6	4	July 22	R = 11.660 L = 12.815	+ 9.9
5	July 12	R = 4.500 L = 4.900	+ 8.9	5	August 26	R = 8.820 L = 7.545	-16.9
6	July 16 (inj. ¹)	R = 3.960 L = 5.105	+28.9	6	April 21	R = 11.100 L = 10.350	- 7.2
7	July 22 (inj. ¹)	R = 1.665 L = 1.820	+ 9.3	7	December 10 (roup)	R = 0.235 L = 0.200	-17.5
				8	December 21 (roup)	R = 0.590 L = 0.635	+ 7.6
Wild Duck							
1	(y'g) Novem- ber 29	R = 0.023 L = 0.027	+17.4	2	December 28 (starved)	R = 0.040 L = 0.040	0.0
					R = 8.3 x 3.2	L = 8.6 x 2.5	

¹ These cocks had been given a few injections of ovarian extract during the week preceding the days of killing and autopsy.

SUMMARY

The prevalence of atrophy of the right ovary in birds; the demonstrated differences in number of primordial germ cells in the two glands of the fowl; and the unequal—and opposite—size relations of the two adult gonads of the male, constitute a body of puzzling facts whose elucidation should contribute largely to our knowledge of the nature and basis of sexual difference.

The right testis of the pigeon is normally larger than the left.

In hybrid pigeons there are more exceptions to the normal size-relations of the two testes than in pure species. The number of the exceptions seems to increase with the degree of hybridization (width of the cross); there being fewer in specific hybrids than in generic hybrids.

The testes of pigeons suffer great reduction in size in disease—particularly in tuberculosis. It is probable that the right gland suffers greater reduction than the left. The left (persistent) gonad of the female does not suffer a similar reduction in tuberculosis. Season is plainly not the cause of the differences and reductions noted in pigeons.

The two testes of the pigeon are characteristically different in their dimensions. The left (like the left ovary) is thinner and more elongate. The right (represented in the female by atrophied ovary) is shorter and thicker.

In poultry the few data at hand fail to indicate a constant or decided predominance of size in either gland.

Cold Spring Harbor, L. I., N. Y. June, 1916

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HYGIENIC CAGES FOR RATS AND MICE

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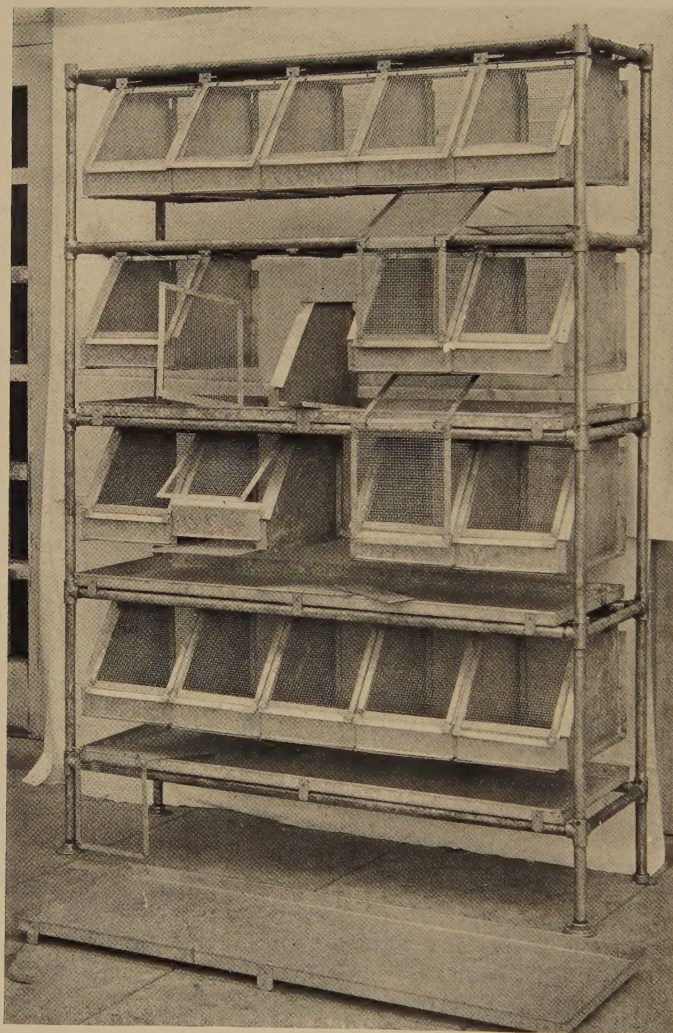
TWO FIGURES

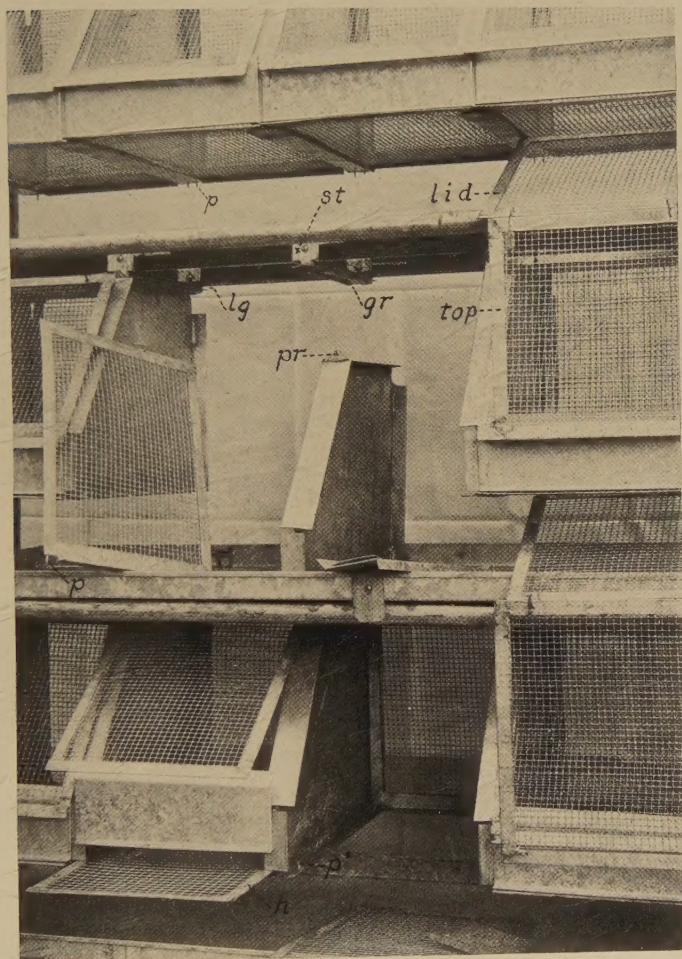
The following is a brief account of cages recently constructed for the Department of Anatomy of the University of California for housing colonies of rats and mice.

In planning these cages the desirability was kept in mind of so designing them that not only might the animals be cared for conveniently, but the cages be easily cleaned and completely sterilized and the spread of infection prevented. Accordingly they were made entirely of metal: the sides and front of galvanized iron, the former preventing the direct passage of infection from cage to cage; and the lid, top, back, and floor of hardware cloth of $\frac{1}{4}$ -inch mesh bound with strips of galvanized iron. They can be taken apart, packed in a small space for boiling, and reassembled quickly without the use of any screws or bolts. All parts are interchangeable. The inside dimensions are: floor, $9\frac{1}{2}$ by $14\frac{1}{2}$ inches; height 11 inches; front $2\frac{3}{4}$ inches high.

They are arranged in groups of 20 (4 rows of 5 each, fig. 1). Each group is supported by a rack made of iron pipe, and 4 pairs of angle irons on which the 4 rows of cages are hung. Below each row is placed a shallow, removable, galvanized iron pan intended to be filled with sawdust for receiving refuse falling through the bottoms of the cages. The racks measure $6\frac{1}{2}$ feet in height, $17\frac{1}{2}$ inches in depth, and $4\frac{1}{2}$ feet in width. There is a space of $9\frac{1}{2}$ inches between the lowest pan and the floor, and 3 inches between the floors of the cages and pans. If desired the racks can be continued upward to carry one or more additional rows.

Most of the details of construction can be seen in figure 2 which shows some of the cages taken down. It will be observed that the sides are suspended and in turn furnish support for the rest of the cage except the top. The sides are put into place by slipping the flanges on the upper edges into grooves (*gr* fig. 2) formed by bending-under the edges of strips of galvanized iron (*st*). A projection (*pr*) prevents sliding the sides in too far. The ends of the strips forming the grooves are bent up and over the angle irons and are permanently fastened by means of bolts. These strips also have soldered to their upper sides grooves (*lg*) opening laterally formed by strips of metal bent in the form of a narrow trough. Into the latter slide the tops to which the lids are hinged by two rings. The backs when in place





rest on the flanges on the lower edges of the sides and against the front faces of the back flanges. The upper ends of the backs are held firmly because they pass behind the rear angle irons; at the lower ends pins (p) fit into holes in the bottom flanges (the pins can also be seen on the under side of the upper row of cages). The binding on the lower edge of each back is turned forward at a right angle and together with the flanges on the lower edges of the sides serves to support the floor. The latter are kept in place by two pins (p') which fit into corresponding holes (h) in the binding. The front is made of one piece of metal. One may be seen endwise resting on the edge of a tray. The ends are bent somewhat in the form of a letter S to form troughs which fit over the flanges on the front edges of the sides.

In assembling the cages the sides are first put into place, then the backs, floors, front, and top (with lid). It will be seen that the floors may be changed without disturbing the rest of the cage, or by removing simply the front. A number of extra bottoms makes it possible to clean one set and have them ready to substitute for soiled ones every week. The other parts of the cages need cleaning only at longer intervals.

For the cages used for rats, floors of $\frac{1}{2}$ inch mesh are provided.

It has been found in actual breeding that 4 and even 6 adult rats can be kept in one cage, and as many as 10 or 12 young rats raised to breeding age in single cages.

The construction of this equipment was worked out by Prof. H. M. Evans and the writer with assistance from Mr. H. B. Foster, the University Engineer.